ANALYSIS OF OPERATION RECOVERY DATA

By Steve Fretwell

Introduction

The purpose of this paper is to develop a method of analysis for data collected at operation recovery and other banding stations which will provide information about variation in the energy reserves of migrants and other groups of birds. The analysis will be based on a simple mathematical model which relates some of the variables (or transformations of variables) which are often measured at O.R. stations. The model will be developed so that unspecified constants may be estimated from small samples using linear regression analysis (a statistical method which finds good estimates of unknown constants in models such as 10, below, given data that are appropriate to the model).

Only the simplest kind of models will be considered here; therefore, they will bear little resemblance to real phenomena. This is only a minor failing, however, since such models are presented more as a catalyst for understanding than as an approximation to reality. Whenever necessary, they will be forced to provide some meaningful interpretation of the results of a standard analytic technique. Hopefully this interpretation will lead to other, non-standard analyses which will eventually permit the development of more appropriate models.

Development of the Model

A bird normally possesses a certain amount of tissue and food in the gut which can be together referred to as energy reserves. When this material is subtracted away from the total body the basic bodily tissues remain. Let the weight of the energy reserves be denoted as ER, of the whole bird as TBW (for total body weight) and of the basic body tissues as BW (for basic weight). Then the introductory sentences can be symbolically expressed in the following equation:

$$BW = TBW - ER$$

which rearranged gives: (1) $TBW = BW + ER$

On any given day a bird starts at dawn with a certain amount of energy reserves. Denote the weight of this material as ER_o. During the course of the day, if the bird consumes more energy than it needs for metabolism, energy reserves are added. Let us assume that the amount added is constant for every hour of the day. Then for each hour of daylight, the bird adds a certain amount of energy reserves, say B_1. After H hours of feeding, the bird will have gained B_1 times H units of energy reserves. Since it started with ER_o the total energy reserves after H

hours of feeding is: (2) $ER_H = ER_o + (B_1 \times H)$

(The ER_H notation means that ER, the energy reserves depends on the number of hours, H, that the bird has been feeding.) The major aim of the following development will be to provide a way of estimating B_1, the rate that energy reserves are added, and ER_o, the energy reserves at dawn.

Replacing ER in (1) with its equal in (2) gives

$$(3)\quad TBW = BW + ER_o + (B_1 \times H)$$

From the work of Greenawalt (1964), the average body weight of birds is generally proportional to the third power of wing length. This is to be expected since wing length is a linear measure while body weight is a mass or volumetric measure. The average body weight of an individual bird is, from (1), equal to the sum of its average basic weight ($\overline{BW}$, the bar denoting average) and its average energy reserves ($\overline{ER}$). That is

$$(4)\quad \overline{TBW} = \overline{BW} + \overline{ER}$$

If the average body weight is proportional to wing length cubed, then denoting wing length by WL,

$$(5)\quad \overline{TBW} = B_2 \times WL^3$$

where B_2 is some constant. Setting the left hand terms in (4) and (5) equal, we obtain

$$(6)\quad \overline{BW} + \overline{ER} = B_2 \times WL^3$$

Let us assume that the basic weight of an individual bird does not vary. This assumption is reasonable, since basic weight is closely related to the fat-free weight minus the non-fat contents and Odum et al. (1964) have shown the overall fat-free weight to be relatively constant. Then the average ($\overline{BW}$) is just the constant value itself, BW. We have from (6)

$$(7)\quad BW + \overline{ER} = B_2 \times WL^3$$

The average energy reserves of a bird, $\overline{ER}$, may be reasonably assumed to be positively related to the basic weight, since energetic requirements increase with size. We will, for simplicity, assume that the relationship is linear, so that

$$(8)\quad \overline{ER} = B_3 \times BW$$

Replacing $\overline{ER}$ in (7) with its equal in (8) gives

$$BW + (B_3 \times BW) = B_2 \times WL^3;$$

$$BW(1+B_3) = B_2 \times WL^3;$$

$$BW = \frac{B_2}{1 + B_3} \times WL^3 ;$$

$$(9) \quad BW = B_4 \times WL^3$$

This relation, with equation (3) yields

$$(10) \quad TBW = ER_o + (B_4 \times WL^3) + (B_1 \times H)$$

This completes the development of the model. In practice, it would be applied to data collected on a single species (or group within a species) on a single day (or period within a day). The constants ER_o, B_4, and B_1 can be estimated if measurements of body weight, wing length, and time of banding are taken.

A more appropriate model might take into account the known relationships between metabolic rate and body size. This would invoke BW to some power other than 1 however, and the added complexity of analysis would probably outweigh the advantages of such refinement.

Discussion

The model (10) must be regarded as preliminary and subject to revision. It is based, for example, on the assumption that energy reserves are added at a constant rate through the day; experience may suggest a more accurate assumption. Also, the basic weight has been related only to the cube of wing length, although it is likely to be related also to tarsus length cubed, or tail length cubed. It may be that adding these variable to the model would appreciably increase the precision of the estimation of ER_o and B_1, especially where only small samples are available.

However, even in its present form the model is useful in that it provides a way of estimating with small samples certain constants which are of considerable value in the study of bird migration. For example, suppose a banding station handles five or more individuals of some species on each of 20 days during migration. The constants ER_o and B_1 can be estimated on each of those days. The effect of season on the rate of accumulation of energy reserves can then be studied by plotting the estimates of B_1 over the dates of migration. The effect of daily temperature on B_1 can then be studied, by comparing estimates on cold days with those on warm days. Perhaps migrants compete for food at stopover areas. This competition would be reflected in the lower estimates of B_1 on days when the density of migrants is high. Estimates of B_1 made at coastal stations could be compared with estimates made at inland stations. If enough individuals are handled in a single day, B_1 can be estimated separately for males and females, or for adults and immatures.

Most of the underlying ideas in the development of the model have

been applied in other forms of analysis (e.g. Mascher, 1966; Helms, 1963; Mueller and Berger, 1966). Usually, however, these analyses have not been based on well defined models developed from stated assumptions. They have required large samples sizes and data from different days have to be averaged, instead of analyzed separately. The present analysis can readily be applied to small samples, and thus permits a finer breakdown of data.

An example is given to provide some familiarity with the kind of results that are obtained in applying model (10). The data were collected by Paul W. Sykes, Jr. and myself on October 2, 1966, on the Outer Banks of North Carolina, and are presented in Table 1. Wing length is presented in decimeters, so that the cubed values are not extreme. The constants in (10) were estimated using regression techniques following Steel and Torrie (1960, p. 283). Note the small sample size - nine birds. This means that the estimates will not be very precise, but are useful when compared with other estimates obtained on other days, or in other places. The estimates are given in Table 2.

Table 1. Data on Brown Creeper, October 2, 1966

Body Weight (TBW) - g.	Wing Length (WL) - dm.	Wing Length Cubed (WL^3) - dm^3.	Hours After Sunrise (H)
7.1	6.8	314	3.3
7.0	6.4	262	4.0
7.3	6.3	250	4.0
7.8	6.7	301	7.5
6.5	6.4	262	7.7
7.2	6.3	251	8.2
8.5	6.7	301	9.0
9.1	6.8	314	10.5
8.1	6.8	314	11.8

Table 2. Estimates of Constants

Constant	Estimate
ER_o	3.1 g.
B_4	.014 g/dm^3
B_1	.122 g/hr.

Summary

A model for use in analyzing operation recovery data in terms of energy reserves for birds is developed and discussed. An example is given.

Acknowledgements

This paper was written while under support of PHS-GM678. I wish to thank H.L. Lucas and Carl W. Helms for reading the manuscript and making helpful suggestions.

Literature Cited

Greenewalt, G.H. 1962. Dimensional relationships for flying animals. Smithsonian Misc. Coll., Vol. 144, No. 2 46pp.

Helms, C.W. 1963. Tentative field estimates of metabolism in buntings. Auk 80: 318-334.

Mascher, J.W. 1966. Weight variations in resting Dunlins (Calidris a. alpina) on autumn migration in Sweden. Bird Banding 37: 1-34.

Mueller, H.C. and D.D. Berger 1966. Analysis of weight and fat variations in transient Swainson's Thrushes. Bird Banding 37: 83-112.

Odum, E.P., O.T. Rogers and D.L. Hicks 1964. Homeostasis of the non-fat components of migrating birds. Science, 1943: 1037-1039.

Steel, R.G. and J.H. Torrie 1960. Principles and Procedures of Statistics. New York, McGraw Hill, 481 pp.

Dept. of Experimental Statistics, North Carolina State University, Raleigh, North Carolina 27607

INCREASE IN NET PRICES

The price of the 12-meter 1¼" mesh tethered net has changed as follows:

	Old Price	New Price
Sustaining Member	$ 3.80	$ 4.50
Active Member	4.30	5.00

This change has been necessitated by an increase in the quality of the 12-meter 1¼" tethered nets. The nylon net is stronger and more resistant to bleaching and air rot; the trammels are tied more securely; and the end loops are colored.

Although this is our first price increase, all prices will go up as soon as our old net stock is depleted and we have to order new ones. It might be well for members to order now before prices increase on their favorite net.

EBBA Net Committee: R.E. Merritt & Richard F. Waechter